SPECIFICATION AS AMENDED

Method for Receiving and Storing Optically Detectable Data

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method of recording and storing optically detectable data of an object on a storage medium.

DESCRIPTION OF RELATED ART

Methods of this kind are used in various wavelength ranges, for example, in the domain of infrared or ultraviolet radiation, of visible light, or of thermal radiation. Appropriate cameras and the associated optics are used, depending on the wavelength range. The object of interest is either recorded as a whole or in separate sections. Each of the individual recordings is of a specific size. Because of the settings of the optical components of the camera, and of the spatial distance between the object and the camera, the recording will incorporate areas that are sharply focused or not so sharply focused. A recording that is sharp in all of its areas cannot be achieved, for only those parts of the object that lie within the focus of the optical system that is used will be clearly focused. The focus is spatially limited and is, in most instances, smaller than the object. Furthermore, if the object is three-dimensional, not all areas of the surface or of the layers that lie immediately beneath the surface can be sharply imaged with the aid of one recording. In addition, it is a further disadvantage that the diaphragm of the camera cannot be opened wide, so that brilliance of the recording is less, since a widely opened diaphragm reduces the depth of focus, with the result that only a correspondingly small part of the object can be sharply imaged.

The prior art (DE 39 31 934 C2, DE 39 05 619 A1) describes an image input and output device that incorporates a focusing system. Using this focusing system, the optical components of the image input device are adjusted sharply to a plurality of different object planes. In order to record image information, a plurality of images of one object are recorded using various settings of the optical components, and the information obtained by doing this is combined. Digital methods are used in order to do this. Using this known device, it is a disadvantage that the variable adjustment of the optical components requires a mechanism that moves the optical components with a very high degree of precision. Such a mechanism is costly to manufacture,

and is vulnerable to damage, wear, and other impairments when it is used. In addition, because of the various optical settings that are used, the information can be assembled only at great cost, since the scale of the images changes for each recording because of the changes to the optical components.

BRIEF SUMMARY OF THE INVENTION

In contrast to the foregoing, the method according to the present invention, which is used for recording and storing optically detectable data of an object entails the advantage that, using one camera, a sequence of a plurality of individual recordings of the object is made using different spatial settings with respect to the position between the object and the camera. The setting used for the optical components, and the resulting focus, remain unchanged when this is done. Because of this, the method is simpler to use than the methods already known from the prior art. A mechanism for effecting precise changes to the optical components is rendered unnecessary. Because of this, application of this method is more cost-effective than previously known methods and it is less vulnerable to impairments, disruptions, or wear when it is used.

The sharply imaged areas of the individual recordings are determined and are assembled, and a plurality of resulting images are formed therefrom. Since the optical components remain unchanged during the different individual recordings, the scale does not change. This leads to the fact that when the individual recordings are being assembled, there is no need to match these with respect to scale. Thus, assembly of the information is less costly that in the case of the known methods.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a flow chart of the preferred method.

Figure 2 is a flow chart of an alternative embodiment of the method.

BRIEF DESCRIPTION OF THE INVENTION

The method of the present invention uses one camera to record a series of individual recordings of the object using different spatial settings with respect to the position between the object and the camera. The settings used for the optical components, and the resulting focus, remain unchanged.

The sharply imaged areas of the individual recordings are determined and assembled, and one or a plurality of resulting images are formed therefrom. Since the settings of the optical components remain unchanged during the different individual recordings, the scale does not change. Thus, when the individual recordings are being assembled, there is no need to match them with respect to scale.

This method can be used to both record individual images of objects as well as to record films. The method can be used manually by cutting out and pasting the sharply focused areas or this can be done by means of screening. However, this method can also be used with the aid of a computer. In the case of two-dimensional objects, or in the case of objects of which a two-dimensional resulting image will suffice, it can be sufficient to assemble the sharp areas to form one single resulting image. In the case of three-dimensional objects, the sharp areas of different planes of the object can be assembled to form one or a plurality of resulting images. The latter case entails the advantage that various features will be shown in different resulting images. Because of this, it becomes simpler to process the images, in particular with respect to recognizing the features. It is also possible to assemble different resulting images for the different depths of penetration into the object that are achieved with the radiation that is used. More advantageously, the individual recordings can be made with the camera lens at larger diaphragm apertures. When this is done, sharp resulting images will be obtained, despite the large diaphragm apertures. This increases the light sensitivity of the recordings. The camera does not have to be sharply focused for each individual recording, since the sharp images are selected electronically, and stored, and images that are not sharp are not stored. Even if the object moves during the recording process, the resulting image will be sharp. The number of individual recordings that are made for each object will depend of the particular application. As a rule, about twenty individual recordings is sufficient. However, in certain cases it may be many more, for example, more than 100 individual recordings, or it may be fewer, for example, five individual recordings. Exposure times will be selected depending on the object and the camera that is used. It depends on the number of individual recordings that a desired per second or per minute. Many types of cameras, for example, CCD cameras, make it possible to reduce the exposure time electronically.

The objects that are recorded can be machines, structural elements, works of art, jewelry; or other valuable items, or they can be individuals or animals. Biometric or anatomical features are used in order to recognize or identify persons or animals, in particular breeding animals,

animals, and these are recorded in the individual images. Both intentional as well as unintentional movements of the object can be used in order to obtain information. Parallel shifts or rotations that are perpendicular to the optical axis are used in order to achieve greater resolution from the camera. Higher resolution can also be achieved by computation. Parallel shifts of the object perpendicular to the optical axis can be evaluated in order to obtain stereoscopic of three-dimensional resulting images even if only one camera is used to record a sequence of individual recordings. When this is done, one exploits the fact that specific areas of the object that has been recorded can be imaged in sequences of individual recordings as their sharpness changes continuously. In this way, it is also possible to obtain information regarding the topography and the surface configuration of an object.

Using a sequence of a plurality of recordings made at pre-set intervals of time, it is also possible to identify dynamic processes of the object. Thus, this method permits the examination of the object over time. This means that movement of an object can be followed and recorded. This recorded movement can be used, for example, to disclose or identify the object or to control specific processes. For example, faulty elements in a production process can be revealed, or an individual can be identified. Intentional movements made by an individual can also supply additional information.

The restricted depth of focus can be used in order to identify, image, and evaluate features beneath the surface of the object. The method according to the present invention permits the use of a large diaphragm aperture. This makes it possible to obtain an image with the specific degree of sharpness.

According to one preferred embodiment of the present invention, the individual recordings are stored in a computer and the sharply imaged areas of the individual recordings are determined by the computer, using digital methods. The resulting images are assembled with the aid of the computer. Specific and suitable software is used for this purpose. This software also determines the limits of the sharply imaged areas. When the resulting image is being assembled, it is also possible to use knowledge of the Trelly method that is known from information theory and signal processing methods. As an example, the individual recordings are stored in RAM or ~~or~~ on the hard disk of the computer. The sequence of individual recordings will only be required until such time as the resulting images is generated. Once this has been done, the sequence of individual recordings is erased.

It is possible to use different methods in order to generate a resulting image. Using a first method, n individual images are filtered with a high pass filter and ~~a~~ sharp areas are copied. When this is done, the transition frequency of the filter is matched to the ranges of sharp focus. This filter can also be made up of a number of different filters. In order to do this, it is possible to use digital methods such as Fourier transformations, wavelet transformations, digital filters, differential or difference formation, as well as Bessel, Butterworth, or Gauss filters. It is also possible to evaluate other information in addition to the sharply imaged areas of the individual images; examples of this are the enlargement or reduction of the imaging relative to the plane of focus in the areas on both sides of the plane of focus. Assembly of the sharply imaged areas of the individual images is effected, for example, with the aid of known digital processes. One or more resulting images will be assembled, depending on the shape of the object and its surface configuration, as well as the number of strata depths or the types of features that are of interest.

In a second method, as compared to the first method, the topology or morphology of the characteristic features of the object are also taken into consideration. As an example, if the object to be recorded is a finger then, using this method, different principle layers and glands as well as, for example, the papillary layer and sweat and sebaceous glands can be evaluated.

When this is done, it is possible to take into account the fact that the papillary lines are largely joined and are on the surface.

In a third method, three-dimensional resulting images are generated from the sequence of individual recordings with the aid of digital functions. Subsequently, such an image can be rotated, tilted, inclined, or moved in any other way, so that the user can see various views of the object on the display screen. This method is particularly suitable in those instances when the data recorded using the method according to the present invention is to be recognized in a data set that is recorded subsequently. Any rotation or shifting of the object in the first data set relative to the second data set can be corrected and compensated for, so that recognition is nonetheless possible.

According to another advantageous version of the present invention, the sharply imaged areas are determined by way of numerical images of the derivative. The derivative is to be formed in

both dimensions of the two-dimensional individual recordings. The derivative is maximal or minimal at the sharply imaged locations. The sharply imaged areas can also be obtained when suitable filters are used, by comparing them with images recorded using different filters.

In another advantageous version of the present invention, the parameters for recording the sequence of individual recordings is predetermined by a computer and the recording sequence is controlled by this same computer.

According to another advantageous version of the present invention, recording the sequence of individual recordings is started automatically. Thus, for example, recording can be started at a specific time or when the object is in a specific position. Recording can also be started when the computer that is processing the individual recordings identifies sharply imaged areas.

In another advantageous version of the present invention, recording the sequence of individual recordings is started by a photoelectric barrier. This method is particularly suitable if the object moves towards and away from the camera during the recording process. The recording is then started automatically if the object approaches to within a specific distance from the camera.

According to another advantageous version of the present invention, the individual recordings are made at precisely fixed intervals of time. Thus, the camera can take twenty-five individual recordings as images or fifty individual recordings as half images each second, and these are then transferred to the computer memory. These values apply in the case of a CCIR standard. Other values will apply in the case of other standards. Not all of the individual recordings have to be sorted in memory. The time for beginning a recording and the time at which storage begins in the computer memory can be different. The underlying principle in this case is that recording the sequence of individual recordings and their storage in the computer memory are processes that are not linked to each other.

According to another advantageous version of the present invention, the individual recordings are made at fixed relative distances between the camera and the object. This can be done, for example, by appropriately arranged photoelectric barriers.

In another advantageous version of the present invention, a CCD camera is used to record the sequence of individual recordings. A line camera or a scanner can also be used in place of the CCD camera.

According to another advantageous version of the present invention, initially all the individual recordings of the sequence are stored in the computer. Once the sequence has been recorded, the sharply imaged areas of the individual recordings are identified and assembled to form a resulting image.

In a further advantageous configuration of the present invention, the sharp areas of each individual recording of the sequence are identified immediately after they have been recorded, and then incorporated into the resulting image. The individual recordings are not stored. Providing the CPU of the computer is operating fast enough, identification of the sharp areas and their incorporation into the resulting image can take place in real time. If this is not the case, then the data relevant to the individual recordings must be placed in intermediate storage. If a plurality of resulting images are generated from the individual recordings, the assembly of the individual resulting images can be effected using different methods. In order to further speed up the recording of the data and storage in the computer, a plurality of processors can be used for assembling one or more resulting images. The interaction of the processors can be organized from different standpoints. On the one hand, the digital computations involved in Methods 1 to 3 described above can be divided into as many sections as can run concurrently. Each section will be processed by a different processor. The processors are synchronized by input, output, or by the end of the process for each section. The data are passed on, or a RAM with more than one access is used (multiported RAM). The assembly of a plurality of resulting images can be effected in part in parallel. Thus, all the resulting images can be formed, even as an object is approaching the camera. To the extent that this is not possible, the missing resulting images will be computed subsequently. This will result in grid patterns with all the information that has been read out or computed.

According to another advantageous version of the present invention, a plurality of resulting images will be assembled from the sequence of individual recordings, with a different area of the object being shown in the resulting images in each instance.

According to another advantageous configuration of the present invention, the plane of the image is divided into a plurality of areas, and these areas are then processed in parallel. This method is particularly suitable if a plurality of processors is available for processing. The areas involved can be squares, rectangles, circles, ovals, or other shapes. These can be adjacent to each other or can overlap each other.

According to another advantageous configuration of the present invention, the method is used to identify the features of a finger, in particular, of a fingertip. In order to record the data, the finger ~~it~~ is brought close to a camera. The process for recording the sequence of individual recordings is started during this approach. Still more individual recordings can be made as the finger is moving away from a camera. For purposes of recognition, particularly characteristic features at the fingertips are identified from the resulting image and are looked for during a repeated recording of the finger. The sweat and sebaceous glands as well as the papillary layer, as well as the openings of the glands on the surface of the skin, which form the dermis and the epidermis, are particularly characteristic features of a fingertip. The papilla are also the basis for the behavior of the skin. The papillary layer, the sweat and sebaceous glands, as well as the openings of the glands on the surface of the skin can be recorded in different resulting images. This simplifies recognition. Using the method according to the present invention, it can also be determined as to whether or not blood flowing through the finger. If the finger is illuminated with a source of infra-red light, a sequence of individual recordings can be made to show variations of brightness as a function of the individual's heartbeat. Furthermore, as blood flows through the fingers, this causes a periodic shift of the cells in the blood vessels within the finger, and this can also be identified with the aid of the method according to the present invention.

According to another advantageous version of the present invention, the object is illuminated with a light source.

According to another advantageous version of the present invention, a pulsed light source is used, and this is synchronized with the camera. The object is only illuminated when an individual recording is to be made.

According to another advantageous configuration of the present invention, the object is illuminated by a plurality of light sources of different wavelength ranges and in different

arrangements. Different types of illumination can be used. Because of the different spatial arrangements, the light will arrive at different angles of incidence. In this way, different spatial, geometric or perspective individual recordings can be made. As an example, flash tubes with different optical filters can be used as the light sources.

Because of the filters, electromagnetic radiation in various wavelength ranges is obtained with the aid of one light source.

According to another advantageous version of the present invention, the object is illuminated only while it is moving toward and away from the camera. The individual recordings are made during this interval of time. In this way, one obtains individual recordings made at different distances from the camera, which are thus of various depths of focus.

According to another advantageous version of the present invention, only those areas of the object that are within focus of the camera are illuminated. This is made possible in that the focus of the camera is not changed between the recording of the individual images. The evaluation and assembly of the individual recordings is simplified in that there is no information from the unsharp areas in the individual recordings.

It is advantageous that a system that incorporates a computer, a camera, and a control device is used it to carry out the method according to the present invention.

Additional advantages and advantageous configurations of the present invention are set out in the Patent Claims.

According to the present invention, all of the features that are set out in the description and in the claims can be used either singly or in any combination with each other, as essential to the present invention.